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Damjan Maletic

Univerza V Mariboru

Matjaz Maletic

University of Maribor, Kranj, Slovenia

Bostjan Gomiscek

University of Wollongong in Dubai, BostjanGomiscek@uowdubai.ac.ae

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The relationship between continuous improvement and maintenance performance

Damjan Maletič, Matjaž Maletič and Boštjan Gomišček

Faculty of Organizational Sciences, University of Maribor, Kranj, Slovenia

Abstract

Purpose - This paper presents an empirical study, which examines the relationship between continuous improvement (CI) and maintenance performance. By examining CI in relation to maintenance performance, this study seeks to the understanding of quality management practices in the field of maintenance.

Design/methodology/approach - The empirical data for this study was drawn from a survey of Slovenian organizations in order to address the research problem. Several statistical methods including correlation analysis, regression analysis as well as principle component analysis (PCA) are utilized to accomplish the objective of the study.

Findings - The findings suggest that CI significantly and positively relates to maintenance performance. In addition, findings advocate the importance of incorporation of quality management practices into maintenance processes.

Research limitations/implications - Based on the findings of this study, it is concluded that future research could broaden the investigation to identify more complex measures of CI. Moreover, sample size should be expanded to a larger group in order to increase the generalizability of the results.

Practical implications - The study contribute to a better understanding of CI activities in the field of maintenance and therefore provide insights for managers to recognize the role of CI activities and understand their effect in enhancing the maintenance performance.

Originality/value - The findings provide empirical evidence that CI is shown to be an effective way of improving maintenance performance.

Keywords: maintenance, quality management, continuous improvement, maintenance performance

1. Introduction

The contemporary global marketplace has been putting enormous pressures on the manufacturing organizations to continuously adapt proactive, innovative strategies for enhancing their manufacturing capabilities (Ahuja and Khamba, 2008). To meet the challenges posed by the contemporary competitive environment, the manufacturing organizations must infuse quality and performance improvement initiatives in all aspects of their processes to improve their competitiveness. Furthermore, in contemporary highly

challenging environment, a reliable production system has been considered as a crucial factor for competitiveness (Pintelon et al., 2006). Thus, for achieving effectiveness, maintenance has to be treated as a strategic issue in manufacturing organizations and to make its proper contribution to profits, productivity, and quality, it must be recognized as an integral part of the plant production strategy (Kumar et al., 2004). Al-Najjar (2007) stated that applying effective maintenance aims to enhance organization's profitability and competitiveness through continuous cost-effective improvement of production process efficiency, effectiveness and productivity, which can be achieved with maintaining and improving the quality of all the elements contribute in the production process continuously and cost-effectively. One of the existing quality initiatives for achieving competitive excellence is, therefore, continuous improvement (Oakland, 1999). Given this increasing role as a driver of competitive advantage, there is a growing body of research on this subject. Terziovski (2006) found out that the most important predictor of productivity improvement was pursuit of continuous improvement (CI). In a review of the literature covering the relationship between quality management practices and organizational performance Lakhali et al. (2006) identified a positive relationship between them. Furthermore, several studies also identify the importance of CI, as a part of quality management practices, in the sense of its contribution to the organizational performance (Kaynak, 2003; Sila, 2007; Terziovski and Samson, 1999; Cua et al., 2001; Douglas and Judge, 2001). Likewise, continuous improvement contributes to the organizational efficiency and effectiveness considering the total productive maintenance (TPM) initiatives (Cooke, 2000). While several studies look at CI in the light of organizational performance, there is still lack of studies that would emphasize the role of CI on maintenance performance. Therefore, using empirical data collected from Slovenian organizations, this study attempts to address the relationship between CI and maintenance performance. Thus, the overall purpose of this paper is to contribute to a better understanding of the integration of continuous improvement into maintenance processes, especially from the maintenance performance point of view.

2. Literature review

2.1 Continuous improvement in maintenance

Total quality includes 'soft' aspects of management such as leadership and organizational culture, and 'hard' aspects such as organizational systems and statistical techniques (Chang, 2005). Oakland (2000) observes that total quality is a management philosophy that has developed incrementally over time, and continues to do so using CI as an important driver. As both quality and maintenance go hand in hand in a manufacturing set up, total quality management (TQM) and TPM share many threads of commonalties like employee involvement, cross-functional approach and continuous improvement (Cooke, 2000). The CI consists of establishing customer requirements (internal or external), meeting the requirements, measuring success, and continuing to check customers' requirements to find areas in which improvements can be made (Chang, 2005). According to Bessant et al. (2001) CI is viewed as a particular set of routines that can help an organization to improve performance. Many researchers view CI as a dynamic process, focus on improvement

programs and their relationship to other organizational elements in the organization and its environment (Nilsson-Witell et al., 2005). In addition, a number of key routines are considered essential if CI is to be developed to its full potential in an organization, such as learning from experiences, capture and deployment of individual learning, etc. (Nilsson-Witell et al., 2005). Oliver (2009) stated that a learning focus can encourage employees to provide feedback to evaluate performance, enabling the outcomes of the CI activities to be incorporated into the knowledge base within the organization. Some authors have also linked CI with maintenance. For instance, Tsang (1998) reported that CI and emphasis on staff development are the key elements of the chosen strategy for maintenance. The previous argument indicates that CI is one of the most important maintenance practices. According to Marquez and Gupta (2006) TPM can help to configure the necessary maintenance organization structure in order to facilitate the CI in maintenance practices. Furthermore, Al-Najjar and Kans (2006) proposed a database for mapping technical and financial effectiveness of production in order to make cost-effective maintenance decisions. Authors stated that database should be built up based on providing possibilities for applying a cost-effective continuous improvement. Moreover, Kans and Ingwald (2008) indicated that information and data need is not a static condition in a maintenance process. For example, continuous changes within different areas of production and market will lead to a continuously changing data need. Consequently, this will affect the information systems used for maintenance, where new features or data are inevitable in order to continuously improve maintenance. In a study (Vassilakis and Besseris, 2009) authors proposed an application of control charts in order to provide vital information regarding the level of control in the selected process. They imply that organization's intention to apply the statistical quality control as part of a 6s scheme in conjunction with an aim for continuous quality improvements will empower the plans for implementation and continuous presence of a TQM culture in the organization. Furthermore, in a study (Maletič et al., 2009) authors presented a conceptual approach (Fig. 1) for CI in the field of maintenance, based on PDCA cycle.

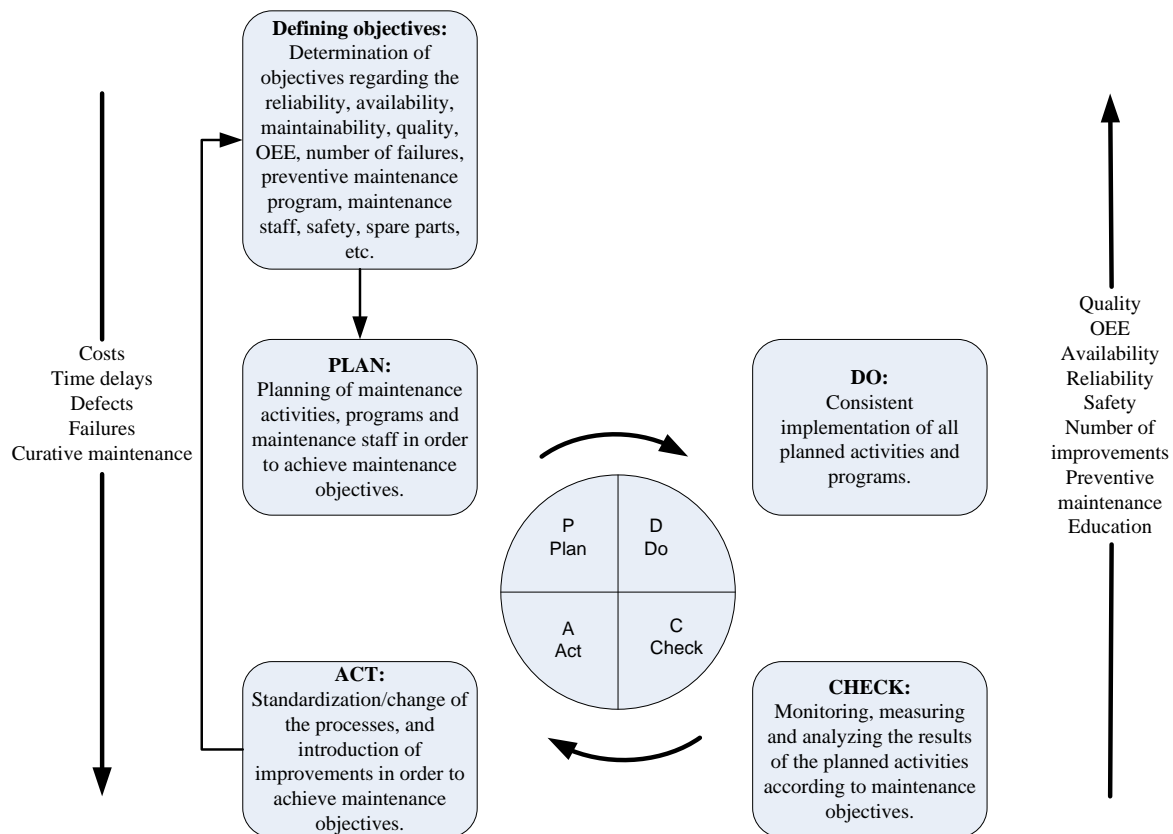


Figure 1: Conceptual approach for continuous improvement in maintenance (Maletič et al., 2009)

2.2 Maintenance performance measurement

The efficiency and effectiveness of the maintenance system play an important role in the organization's success and development. Therefore, the system's performance needs to be measured using a performance measurement technique (Parida and Kumar, 2006). Hence, Åhrén and Parida (2009) reported that the measurement of maintenance performance has become an essential element of the strategic thinking of assets owners and managers. Performance measurement is, therefore, a fundamental principle of management. Muchiri et al. (2011) stated that like other manufacturing functions, performance measurement is important in managing the maintenance function. In addition, performance measures provide an important link between the strategies and management actions and thus support implementation and execution of improvement initiatives (Neely et al., 2005). Further, they can potentially help maintenance managers to focus maintenance staff and resources to particular areas of the production system that will impact manufacturing performance (Muchiri et al., 2011). According to Parida and Kumar (2006), the following factors are considered as most important factors, justifying the implementation of a maintenance performance measurement process:

- measuring value created by the maintenance,
- justifying investment,

- revising resource allocations,
- health, safety and environment issues,
- focus on knowledge management,
- adapting to new trends in operation and maintenance strategy and
- organizational structural changes.

In order to utilize maintenance performance measurement and management to promote positive and proactive organizational change, the maintenance performance management system should be designed to track and improve different aspects of the maintenance effort (Simoes et al., 2011). Given the fact that maintenance plays an important role in achieving organizational goals (Tsang, 2002), and the fact that CI is a part of quality management as well as maintenance practices (Cooke, 2000), which aims to contribute to the effectiveness, there is certainly a need for a performance measurement system.

3. Methodology

3.1 Sample

This study utilized a survey of a sample of Slovenian organizations, encompassing various sectors. One survey was sent to each organization. Of the 53 organizations included in the final sample, 26.4 per cent were small sized organizations employing 50 employees or less, 43.4 per cent were medium sized organizations, employing 51 - 250 employees, 9.4 per cent organizations were with 251 – 500 employees and 20.8 per cent organizations were with more than 500 employees. The questionnaire was responded by manufacturing, construction, transportation and other types of industry, in portion of 77.4%, 7.5%, 3.8% and 11.3%, respectively.

A power analysis shows that the sample size used in this study meets or exceeds the sample size requirement for a power level of 0.8 at probability level 0.05.

3.2 Measures

Several topics (related to quality management practices and maintenance performance) were conceptualized to formulate the questionnaire, each tested on five-point Likert scales (1 = “strongly disagree”, 5 = “strongly agree”).

Table 1. Construct validity and reliability

Factor	Items	Factor loading	Cronbach's alpha	Mean (S.D.)
Continuous improvement	We deploy the principles of total productive maintenance (TPM) - CI_I	.836	.936	3.04 (1.208)
	The teams are used in the field of maintenance - CI_II	.847		3.77 (1.031)
	We systematically monitor the	.921		3.35 (1.235)

	proposals and suggestions for improvements in maintenance processes - CI_III			
	We use tools for continuous improvement in maintenance processes CI_IV	.928		3.21 (1.126)
	We continuously inform the employees in the field of maintenance about the quality of processes and products, with the purpose of maintenance processes improvement - CI_V	.881		3.23 (1.293)
	Management is committed to continuous improvement in maintenance - CI_VI	.821		3.63 (1.189)
% of variance	76.28			
Maintenance performance indicators	We are achieving high Overall Equipment Effectiveness (OEE) – MPI_I	.893	.879	3.39 (1.145)
	We are achieving high availability of assets - MPI_II	.877		3.61 (.954)
	We are achieving times between failures (MTBF), which are in accordance with the manufacturer's specifications - MPI_III	.844		3.22 (.987)
	We are assuring a high level of reliability and confidence in relation to customers - MPI_IV	.815		4.07 (.929)
% of variance	73.576			

3.3 Research methods

The following research methods were used in the study:

3.3.1 Exploratory factor analysis. For the purpose of validating the measurement instrument we used an exploratory factor analysis.

3.3.2 Correlation analysis. According to the presumption of the proposed link between CI and maintenance performance, the test of measuring the association of variable was Pearson correlation.

3.3.3 Principal component analysis (PCA). Data were analyzed using multivariate data analysis (MVDA), mainly to obtain an overview of the data and look for influential variables, clusters and trends. Principle component analysis (PCA) was used and the results were displayed graphically, applying a free software environment for statistical computing and graphics R. We used the PCA model to get a deeper insight into the CI activities, by plotting the PCA scores and loadings on the same plot.

3.3.4 Regression analysis. Regression analysis was used in order to analyze the relationship between a dependent variable (maintenance performance) and independent or predictor variable (CI).

4. Results

4.1 Construct validity and reliability

In order to confirm the latent factor structure for measured variables, an exploratory factor analysis was performed. To test the reliability, the internal consistency of the questionnaire was measured using Cronbach's alpha coefficient. The results of validity and reliability are presented in Table 1.

The Pearson correlation matrix (Table 2) shows that CI variables are positively and significantly related with maintenance performance. As can be seen in Table 2, the strongest relationship was found between CI_IV and maintenance performance ($r = .766$, $p < .01$). Variable CI_V is also strongly related to maintenance performance ($r = .760$, $p < .01$). Furthermore, our results support a significant positive correlation between CI_II ($r = .752$, $p < .01$), CI_VI ($r = .678$, $p < .01$) and CI_III ($r = .677$, $p < .01$), and maintenance performance. However, the correlation analysis revealed that weakest correlation is between CI_I ($r = .639$, $p < .01$) and maintenance performance, but, it is still significantly positive.

Table 2. Correlation matrix

Construct	Correlation matrix						
	1	2	3	4	5	6	7
CI_I	1						
CI_II	.711**	1					
CI_III	.713**	.686**	1				
CI_IV	.745**	.734**	.848**	1			
CI_V	.637**	.690**	.760**	.769**	1		
CI_VI	.501**	.590**	.694**	.666**	.681**	1	
MPI	.639**	.752**	.658**	.766**	.760**	.678**	1

** Correlation is significant at the 0.01 level (2-tailed)

The correlation matrix can also be visualised with the PCA biplot, (Fig. 2). To explore the correlation between variables (CI variables) the principal component loadings are used. The eigenvalues indicate that two components (cumulative proportion of variance for two components) provide a reasonable summary of the data, accounting for almost 84% of the total variance.

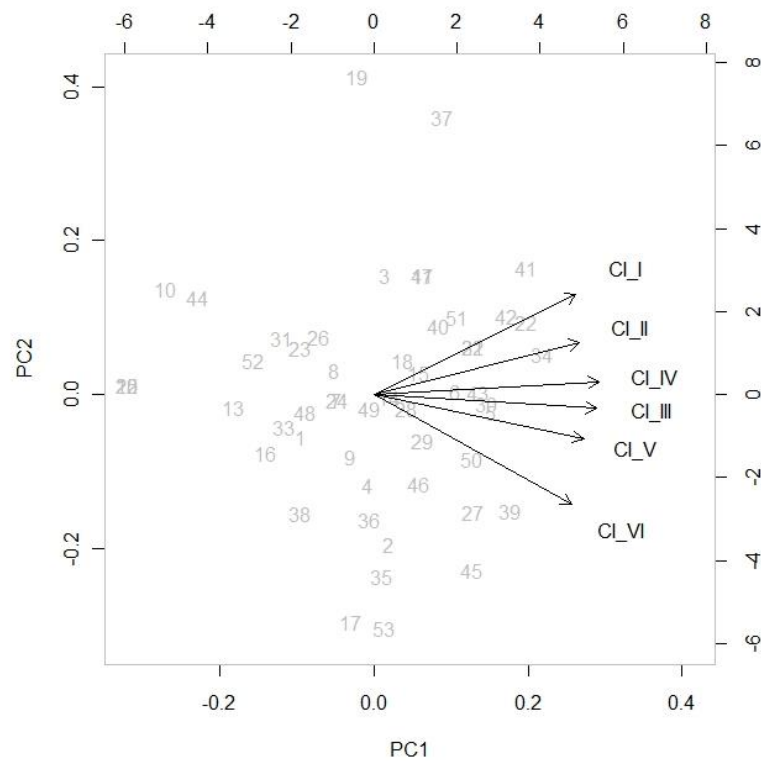


Figure 2: The PCA biplot

From the biplot (Fig. 2) one can see that the variance along the Comp. 1 axis is higher than along Comp. 2 axis. Lines pointing in the same direction correspond to CI variables which are correlated. Note firstly that all variables have a high loading on PC1, indicating that PC1 appears to be a measure of overall CI. Note secondly that in PC2, the variables fall into two slightly distinct clusters, implying the existence of two distinct CI segments. As the biplot of the first 2 principal components shows, CI_I and CI_II contribute most to the first and second principal components, respectively. Only the coefficients associated with the variables CI_I, CI_II and C_IV have positive loadings on the second component. This indicates that PC2 is primarily measure of the TPM principles.

Results of the regression analysis (Table 3) show that the linear model tested is significant ($p < .01$). The regression analysis accounted for 67.1% change is caused by continuous improvement which is dependent variable. Value of beta also shows that continuous improvement is important predictor of maintenance performance (Beta = .819, $p = .000$).

Table 3. Regression analysis

R – Square	F – Change	N	Sig. F - Change
.671	89.592	53	.000
Independent variable	Standardized coefficient (Beta)	T	Sig.
Constant		4.848	.000
Continuous improvement	.819	9.465	.000

Predictor: Continuous improvement

Dependent variable: Maintenance performance

Table 4 shows the results of independent t-test. Mean values were estimated in order to show the relationship between ISO 9001 and maintenance performance. The result shows that according to t-test, the difference between means is not significant.

Table 4. Results of independent sample t-test for comparing of maintenance performance between organizations that have implemented ISO 9001 and organizations without ISO 9001 compliance

QM approach		N	Mean value	Mean Difference	t-value	p-value
ISO 9001	Yes	34	3.6176	.13738	.585	.561
	No	19	3.4803			

*Significant at the 0.05 level (2-tailed)

5. Discussion

In this study we have provided empirical evidence that CI has a positive impact on maintenance performance. As shown by the regression results (Table 3), CI is an important predictor of maintenance performance (Beta = .819, $p = .000$). From theoretical perspectives, this finding could be interpreted in the light of the organizational performance. One explanation of this could be the argument, that an effective maintenance could influence the profitability of a manufacturing process through its direct impact on quality, efficiency and effectiveness of operation (Alsyoud, 2007). Having this in mind, we can support our result by the findings of studies (Cua et al., 2001; Douglas and Judge, 2001; Kaynak, 2003) which have shown the positive relationship between quality management practices and organizational performance. CI is in organizations often introduced as part of quality management systems, such as ISO 9001. Since its advent, ISO 9000 has also been an important research topic within management literature. In particular, previous literature has evaluated the relationship between ISO 9000 certification and organizational performance and reported mixed results (Prajogo, 2011). For example, studies of Terziovski et al. (1997) and Singels et al. (2001)

found no evidence of a link between ISO 9000 and organizational performance. On the other hand, Feng et al. (2008) found a positive and significant relationship between ISO 9000 and operational performance. However, based on the results of this study (Table 4), we did not find the evidence that organizations with ISO 9001 compliance, achieve better results in term of maintenance performance. Nonetheless of this finding, we believe that if organization focuses on CI solely as systematic approach for striving to achieve improvements in maintenance processes, these results in better maintenance performance.

The findings of correlation analysis provide further understanding of the variables, with respect to their correlation with maintenance performance. As evidenced by the correlation analysis presented in Table 2, tools for CI and information concerning the quality of processes are the most significant activities regarding maintenance performance. This is in line with study of McKone et al. (2001), in which they found a positive relationship between TPM measures, among which were also teams and information tracking, and manufacturing performance. The finding about information flow could also be supported by the study of Seth and Tripathi (2005) in which they revealed a positive relationship between information architecture (information and data needed to support key processes and performance improvement) and performance factors. The findings, therefore suggest that information provides necessary infrastructure to facilitate decisions in right direction. Furthermore, positive result on the relationship between the tools for CI and maintenance performance support the study of Duffuaa and Ben-Daya (1995) in which authors highlight the idea of applications quality tools in different maintenance activities in order to improve maintenance quality.

As evidenced by the correlation analysis presented in Table 2, teams are shown to have a significant and positive relationship with maintenance performance. The results is consistent with the finding of the literature stream which considers team work as an encouragement of participation of all employees, including the operatives who are ideally placed to make a significant contribution to improving performance (Bond, 1999). Furthermore, the result also support the discussion in TPM literature concerning the role of TPM in achieving manufacturing performance, where teams are considered as an important component in achieving high availability, production efficiency and better quality (Sharma et al., 2006). As such, organizations with team based maintenance strategy will perform better. This could be also argued for a management commitment, which also appears to have a significant role in maintenance performance, according to our results from the correlation analysis. The finding, therefore, implies the importance of management commitment to CI in achieving high maintenance performance, which can be interpreted by the argument, that management commitment is one of the key factor in implementation of the TPM, as well as TQM (Hansson et al., 2003). The results presented above are also consistent with finding that principles of TPM are positively correlated to maintenance performance. In particular, the finding support the notion that TPM could benefit to the maintenance performance. This is in line with the assertion that TPM describes a synergistic relationship among all organizational functions, particularly between production and maintenance, for the continuous improvement of product quality, operational efficiency, productivity and safety (Labib, 1999).

The results of PCA correspond to the findings of Factor Analysis, indicating that proposed variables correctly reflect the measure of CI. Furthermore, finding of PCA, support the results of the correlation analysis. As it is shown by results of PCA (Fig. 2), all variables of CI are strongly correlated. By comparing the score and loading plot, we can also identify the relationships between samples and variables. Based on the position of the observed cases (marked with numbers), one can infer at which cases the variables (CI) were correlated. Moreover, we can also link the findings of PCA with maintenance performance measure. It appears that organizations with a high level of maintenance performance (see number 5, 15, 22, 32, 34, 37, 39, 41, 42, 50) show significantly higher scores on the first principal component in comparison to organizations with low maintenance performance (i.e. 10, 13, 16, 44). This leads us to conclusion that integrating CI practices in maintenance processes is considered to be an important element in achieving higher maintenance performance. However, one can also easily identify outliers, i.e. organizations that have different characteristics in comparison to other organizations in the same group (i.e. 19, 37).

From a managerial perspective, the study emphasizes the need to recognize the importance of CI activities, particularly their roles in influencing the outcomes of the implementation of CI into maintenance processes. Two practical insights can be drawn here. First, it is important for managers to recognize the role of CI activities in the field of maintenance and understand their effect in enhancing the maintenance performance. Second, from the results we can infer that positively correlated CI activities could reflect in better maintenance performance and could therefore also represent a benefit to manufacturing performance. This could lead to competitive success, and from that perspective we acknowledge our findings also as a practical contribution for the organizations.

7. Conclusion and future directions

The results supported empirically the theoretical assertions made in the study. Therefore, in response to the purpose of this paper, the findings provide empirical evidence that CI significantly and positively contributes to maintenance performance, in terms of maintenance processes efficiency and effectiveness. CI is shown to be an effective way of improving maintenance performance. Although continuous improvement is widely accepted approach in the field of quality management, it is still in the development in the evolution of maintenance management theory (mainly in the context of maintenance performance) and practice. As such, the emphasis is currently on the role of CI as a part of TPM practices and its correlation with manufacturing performance, rather than on the creation of direct relationship between CI and maintenance performance.

There are a few limitations of the study that present directions for future investigations in this domain. Despite the fact that our study results in valuable insights into CI, in particular in the maintenance performance context, there are some limitations. First, our study focused on one specific factor that may influence maintenance performance. Future research could broaden the investigation to identify more complex measures of CI. It could also be focused on moderating effects of various contextual factors (such as quality orientation) on the

relationship between CI and maintenance performance. Second, our sample size should be expanded to a larger group in order to increase the generalizability of the results.

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